Hardware Development of Microcontroller Based Impedance Relay with Interconnection to TLS

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Abstract

Transmission lines being spread over thousands of kilometers and exposed to all atmospheric conditions, they are the most likely to be subjected to faults. Distance relaying for transmission line protection being evolved after overcurrent protection schemes, distance relaying overcomes the major drawbacks of simple overcurrent protection. Many advanced quadrilateral relay characteristics being used these days for the protection of EHV and UHV lines are developed from basic impedance relay characteristics. This paper presents microcontroller-based relay hardware developed for the protection of transmission line simulator model in lab for real time fault detection and isolation of faulted section. Zone selection, adjustable set point values, characteristics selection through keyboard interface, accurate displaying of type of fault, fault impedance and phase angle are the key features of developed hardware. The performance of the developed hardware is analyzed on TLS model for transmission line of Twin moose conductor of 400 KV with different zones and different characteristics

Keywords: *Protection of transmission line, Distance protection scheme, Microcontroller based distance relay, transmission line simulator.*

1. Introduction

Transmission lines are the most crucial part of power system and are used for transfer of power from generating station to the load end. Being open to sky, many external parameters like dust, dirt, ice loading, wind pressure etc. affect the performance of transmission lines.

As transmission lines have the highest fault incidence ratio. Many advanced relaying schemes are developed and implemented for TL protection. Distance relaying for TL protection is developed to overcome the variable reach problems associated with overcurrent protection depending upon type of fault and fault resistance. Advancement in numerical relays has affirmed ease to design the distance relaying scheme of many complex characteristics and thus, distance relaying is used for protection of EHV and UHV transmission lines. [2].

This paper presents the microcontroller-based distance relay scheme interfaced with TLS for protection from various faults. As the present setup in lab provides merely overcurrent protection [3]. This paper presents implementation of basic distance protection scheme for TLS. Micro controller-based hardware interface is developed with user friendly keyboard interface for selection of different characteristics, different set points, different zones.

2. Transmission Line Simulator (TLS)

Transmission line simulator (TLS) is the sophisticated module designed for students to understand basic concepts of power transmission lines and their performance after incidence of different fault conditions. The basic block diagram of TLS is as shown in figure 1.

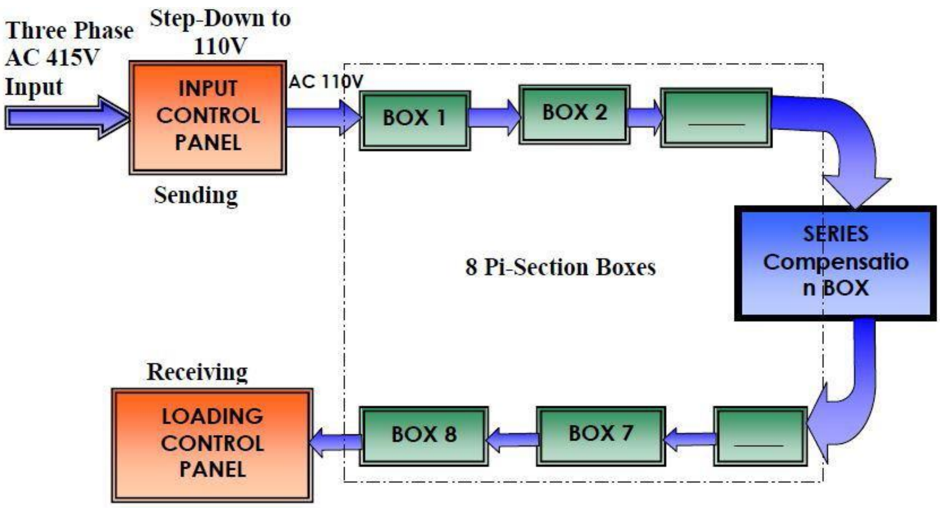

Figure 1.Block Diagram of Transmission Line Simulator (TLS)

TLS has eight Pi sections connected in series having series resistors, series inductors and shunt capacitors to simulate transmission lines upto 400 KV and 200 kilometers. Each Pi section represents the maximum line length of 25 kilometers. Series compensation box consists of series capacitors used for line compensation. Input control panel has metering and relay having overcurrent characteristics while loading control panel allows user to control resistive inductive and capacitive load. TLS allows user to observe actual line parameters like effect of series compensation upon voltage profile, Ferranti effect, effects of fault incidences on line etc through software user interface Power TLS. [3]

3. Impedance and other Basic Characteristics of Distance Relaying

Impedance relay is a voltage restrained overcurrent relay and it measures the impedance of the line section between relay location and the point of fault, proportional to the line length i.e. distance of fault from the relay location. The relay is supposed to send the trip signal to the breaker whenever the impedance measured by relay is lesser than the set value of impedance. Being versatile family of relaying, this scheme is use for protection of heavy transmission lines. Impedance, reactance and mho are the basic characteristics of distance relaying. In the simplest distance relaying scheme, relay is generally placed at the sending end bus of the transmission line as shown in figure 2 and is supposed to look after forward direction faults i. e. relay should sense the faults beyond the relay location and protect the line beyond itself.

The selection of particular characteristics of distance relay is decided majorly by the effect of power swings and arc resistance. Reactance relay occupying the largest area on RX plane and characteristics being straight line parallel to X axis, remains unaffected by the arc resistance making it preferable for ground fault relaying. In the short transmission lines, line impedance is small and comparable to arc resistance but the effect of power swings remains for shorter period. Therefore, reactance relay can be used for detecting phase faults in Short transmission lines.

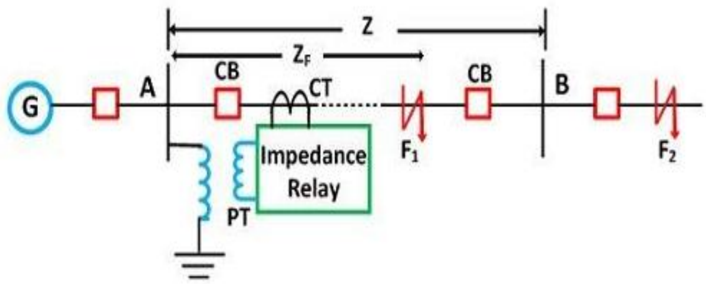

Figure 2.Location of impedance relay on the transmission line to be protected [4]

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In case of long transmission lines, effect of power swings acts as decision making factor as power swings in long transmission lines stay for longer periods. Mho relays occupying the least area on RX plane amongst impedance, reactance and mho characteristics and being the least affected by power swings, they are more suitable for long transmission lines.

Impedance relay representing circle with center at origin on RX plane, is moderately affected by power swings and arc resistance and is suitable for protection of medium length transmission line from phase faults.

Many more advanced characteristics like quadrilateral, elliptical, hyperbola as blinders and specially shaped line dedicated characteristics are being evolved and implemented due to advancement in numerical relaying. Impedance reactance and mho relay characteristics have proved to be basic building blocks of modern, composite and miscellaneous transmission line protection schemes despite of being imperfect. [6]

4. Hardware Implementation

The voltage and current range of the hardware implemented is selected in relation to TLS range parameters. The input voltage to TLS is 415 V 50 Hz and it is internally stepped down to 110 V Line voltage in the input control panel. The max current limit of TLS is 5 A. Accordingly, the voltage and current limits of designed hardware is 85 V (phase to ground) and 5 A. The basic block diagram of the implemented relay hardware is as shown in below figure 3.

Three voltage signals and three current signals are fetched from TLS through PTs and CTs and are fed to microcontroller through signal conditioning circuits consisting of filters. The butterworth filter, being low pass filter, designed to cutoff frequency of 72 Hz is used as operating frequency of the TLS unit is 50 Hz. LM358N Opamps are used as zero crossing detectors for all phase phase voltage and current signals. Six analog inputs of three phase voltages and currents are fed to microcontroller ADC channels. Six

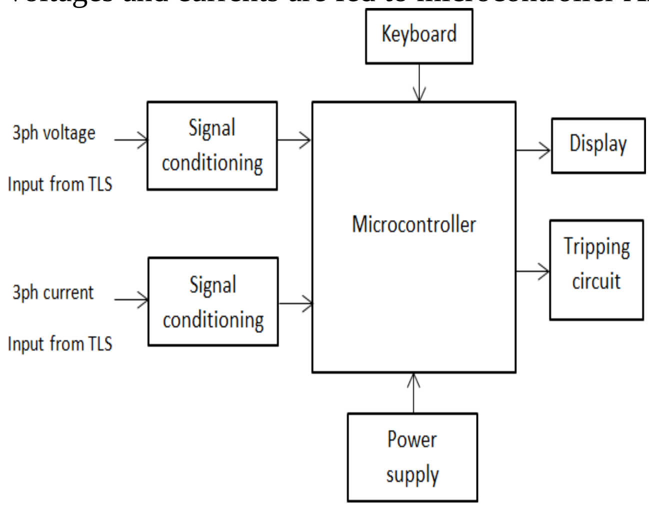

Figure 3: Block diagram of the hardware setup.

ZCD outputs are fed to the microcontroller as digital inputs for detecting phase difference between voltages and currents of corresponding phases. The controller used is dsPIC controller having internal memory of 1 KB and conversion rate of 1msps with 6 MHz crystal giving execution time of 60 nsec.[5].

The 20*4 LCD display is used as human machine interface to display parameters like voltages, currents, type of fault etc after selection of parameters like type of relay characteristics, set value of the relay, zone selection etc. through 4 key keyboard. Set value range is 150 ohm to 240 ohm that can be fed through the keyboard. In the stability point of view, input voltage lower limit is decided. If the input voltage is lesser than 35 V for any phase, microcontroller considers it as the fault on all three phases. The fault indication is given through LCD display and red LED display. LED on the inbuilt relay driver circuit glows whenever there is fault condition observed on the TLS and further drives the breaker through relay driver circuit. The snapshot of designed hardware is given in figure 4 and figure 5.

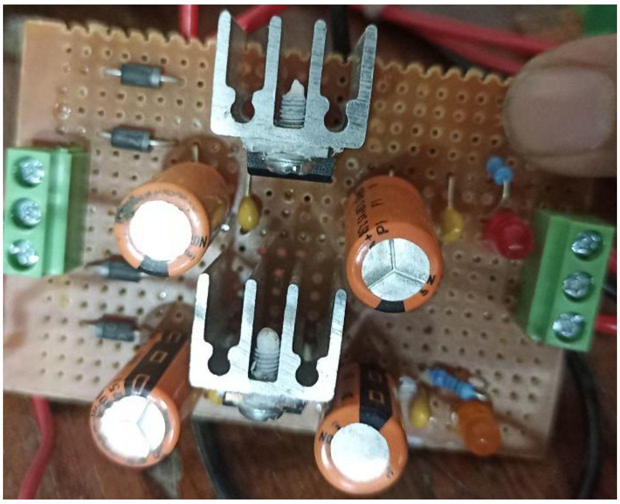

Figure 4. Power supply circuit implemented through hardware on general purpose board

This system as a whole works on 230 V 50 Hz AC supply independently of line parameters of TLS. This AC supply signal is fed to 7805, 7905, 7812, 7912 through PT, rectifier and filter to get +5 V, -5V, +12 V and -12 V DC voltages respectively for operation of microcontroller and relay driver circuit. The circuit as a whole is tested on general purpose board earlier and mounted on PCB. Adjustable zones setting facility is also given.

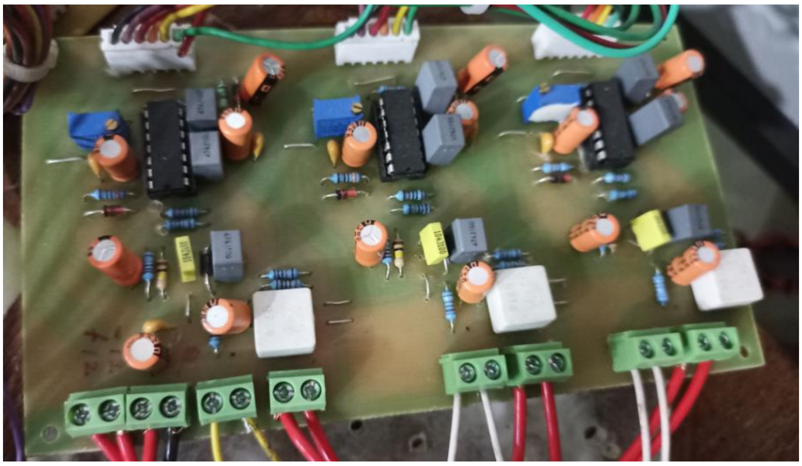

Figure 5. Three phase voltage and current signal conditioning circuits implemented through PCB

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While calculating impedance of line as seen from the relay location, rms values of phase voltage and line current are considered. Calculations of impedance and components of impedance are done and the decisions are made. Accuracy of measurement process is ensured with repeatitive measurement parallelly with fault identification.

Z=V/I, if Zmeasured<Zset then trip otherwise restrain
X= Z sin Ø , if Z sin Ø<Kset then trip otherwise restrain
M= Z/ cos (Ø - α), if (Z/ cos (Ø - α)) <Kset then trip otherwise restrain

Firstly, type of relaying characteristics, set points, zones are defined by user with keyboard. Three phase voltages, currents and their respective phase angles are monitored continuously and compared with set values to make tripping decision. The monitoring is continued until any kind fault is detected and trip signal is generated accordingly to isolate faulty part of the line[6]. Zone 1 is set for 80% of total line length and the further part of line is covered in zone 2. Relay being the backup protection for zone 2, time setting is accordingly adjusted and is given 2 sec for zone 2 and 4 sec for zone 3 as of now to manually crosscheck but is can be adjusted through program.

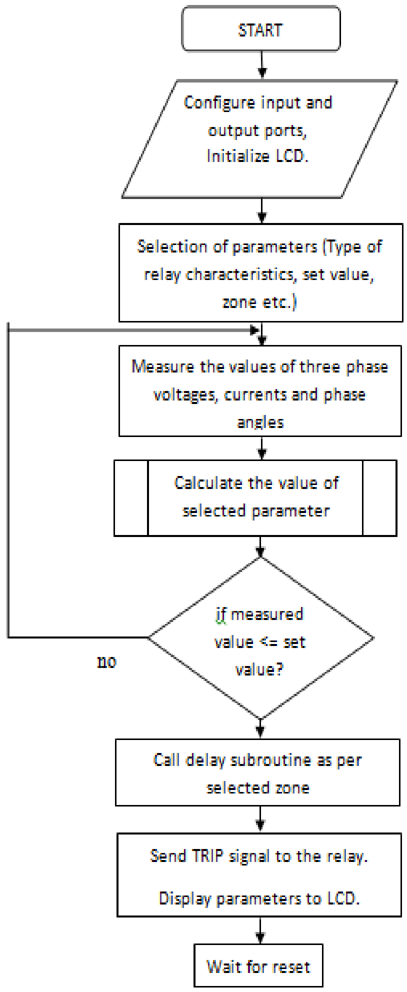

Figure 6. Flowchart of programming

5. Line Parameter Selection on TLS

Power TLS software that allows the user to select various line parameters like type of conductor, voltage level, line length, loading and number of Pi sections, auto-calculates the other parameters like actual line current, simulated line current, practical line parameters (like resistance, inductance, capacitance) etc. and allows the user to choose combinations of R, L and C on pi sections to match the total values with software calculated value. User has to put the respective switches ON/ OFF to get the simulated line as a replica of actual line. Different line combinitions were selected and 1000+ readings were taken from TLS panels that aresummerised in the table 1.

Table 1: Full Load impedance Values and Impedance Value Ranges for Three Different Zones for Different Line Parameters Simulated on TLS

SN	Line description	Z_{FL}	Z for Zone 1	Z for Zone 2	Z for Zone 3
1	Racoon 33 KV 2 Pi sections 100 MVA 2km	619	36.75 to 47.91	41.9 to 54.4	46.81 to 58.86
2	Panther 110 KV 2 pi sections 100 MVA 5 km	598	33.60 to 45.95	37.39 to 48.80	40.19 to 52.79
3	Twin moose 400 KV 2 pi sections 12 MVA 30 km	398	33.73 to 45.98	38.39 to 48.8	40.45 to 50.97

(All value are in ohms)

Z= Impedance (voltage to current ratio)

5. Results

Three characteristics i.e. Impedance, Reactance and mho relay algorithms are developed and hardware is tested by simulating line parameters on TLS. Seven Pi sections of TLS are taken in circuit and three zones each of 30 km are simulated on TLS. The following line parameters are selected for example and results are given as per the selected line parameters for testing the designed hardware.

Conductor type: Twin moose
Voltage: 400 KV
Line length: 30 km
Load= 12 MVA
Number of pi sections: 2

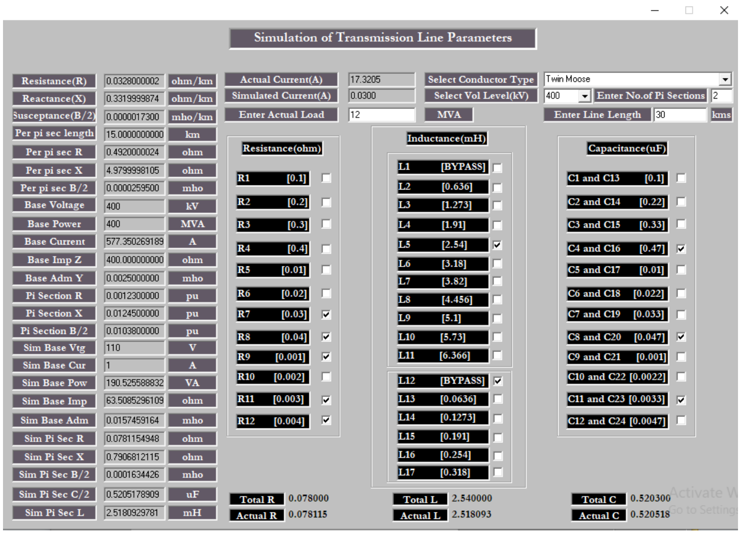

Figure 7.Line Parameter Simulation (Power TLS Software)

Various faults are created in different zones of simulated transmission line and readings obtained from TLS input panel metering and microcontroller based hardware display after incidence of various faults are tabularized below.

(V=Voltage in volts, I= Current in amperes, Z= impedance in ohms)

Table 2: LG fault in zone 1 (Fault on Y phase)

	TLS readings				Relay display readings					
Phase	No load		Full load		No Load			Full load		
	V	I	V	I	V	I	Z	V	I	Z
R	62.93	0.137	62.93	0.312	63	0.14	467	63	0.3	202
Y	59.47	2.48	59.47	2.52	58	2.48	23	59	2.5	24
B	60.62	0.137	59.47	0.312	60	0.14	441	59	0.3	189

Figure 8.LCD display showing fault details of SLG fault

Table 3: LLG fault in zone 2 (Fault on R and Y phase)

	TLS readings				Relay display readings					
Phase	No load		Full load		No Load			Full load		
	V	I	V	I	V	I	Z	V	I	Z
R	60.62	0.132	60.62	0.342	60	0.13	462	59	0.341	173
Y	49.65	2.24	49.07	2.25	50	2.26	22	59	2.25	26
B	58.89	2.09	58.89	2.18	59	2.1	28	63	2.13	30

Figure 9.LCD display showing fault details of LLG fault

6. Conclusion

This paper presents the hardware implemented to interface with TLS for identification of fault through impedance, reactance and mho relay algorithm with adjustable zone setting. The hardware is successfully tested with different types of faults on 400 KV 30 km Twin moose conductor with three zones. The developed relay algorithm works satisfactorily and trip signals are generated with identification of fault with accuracy. The relay has inbuilt power supply circuit with the input of 230 V 50 Hz AC which is independent of TLS supply. Fault identification with impedance, reactance and mho characteristics with adjustable zones is the key feature of the designed hardware over existing overcurrent relay characteristics inbuilt in TLS hardware. The setup may help students further to study distance relaying on TLS in Power System laboratory.

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